200 and 400 GHz Schottky diode Multipliers Fabricated with Integrated Air-Dielectric (Substrateless) Circuitry

E. Schlecht, J. Bruston, A. Maestrini, S. Martin,
D. Pukala, R. Tsang, A. Fung, R. P. Smith, I. Mehdi

SWAT Team

Submillimeter Wave Advanced Technology

11th International Symposium on
Space Terahertz Technology

2 May 2000

Acknowledments

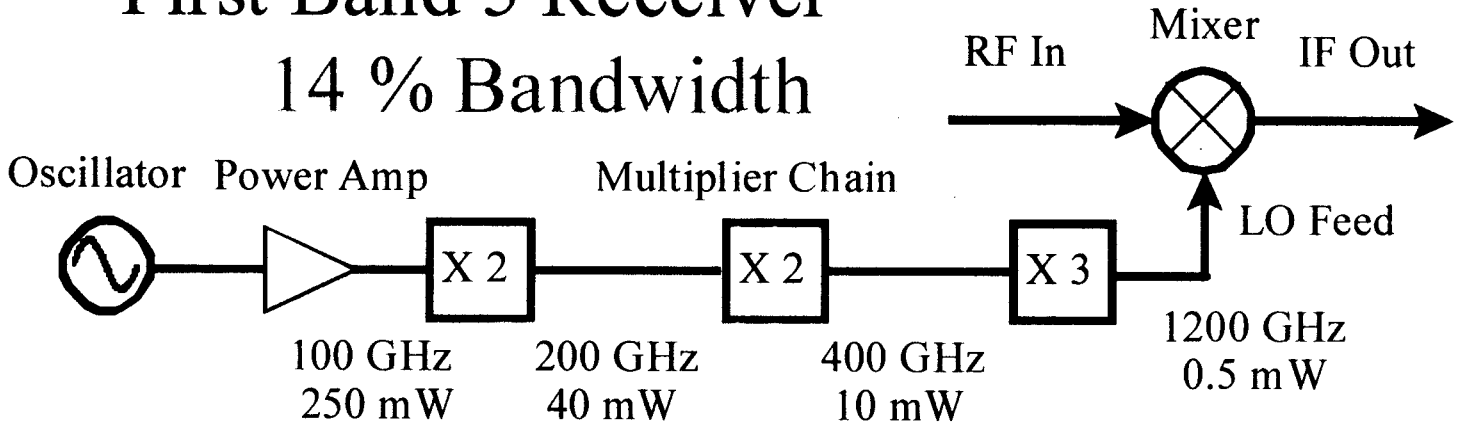
- Thanks to Barbara Nakamura for processing work
- Thanks to Dr. Neal Erickson for technical discussions
- Thanks also to Dr. Peter Siegel for initiating and supporting the planar diode work at JPL

- The research described in this publication was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration

Missions Needing Submillimeter LO Systems

- High-resolution spectroscopy for Earth, planetary and astrophysical observation
- Typical missions are FIRST, Cloud Ice, AMLS, ...

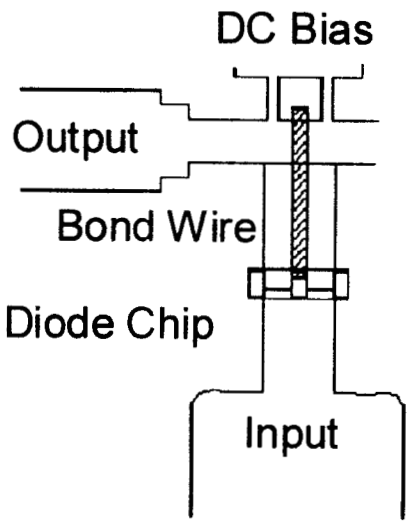
First Band 5 Receiver
14 % Bandwidth



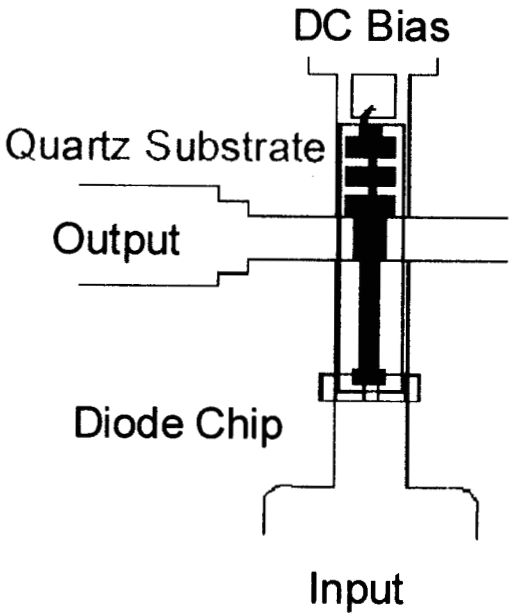
Multiplier Requirements for FIRST

- Efficient, accurate assembly of multiplier circuits in blocks — need over 100 for FIRST!
- Ruggedness, resistance to shock and vibration for space qualification
- Wide bandwidth (10 to 14 %)
- High power capability (200 – 250 mW)
- High efficiency for multiple cascaded stages
- Cryogenic (100 K) operation

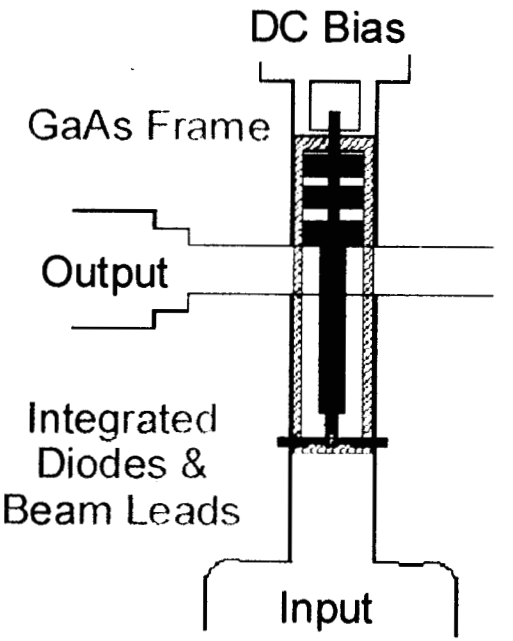
Planar Balanced Doubler Technologies Based on Neal Erickson Split- Block Concept



- Chip soldered to block
- Bondwire connects chip to DC Bias Cap

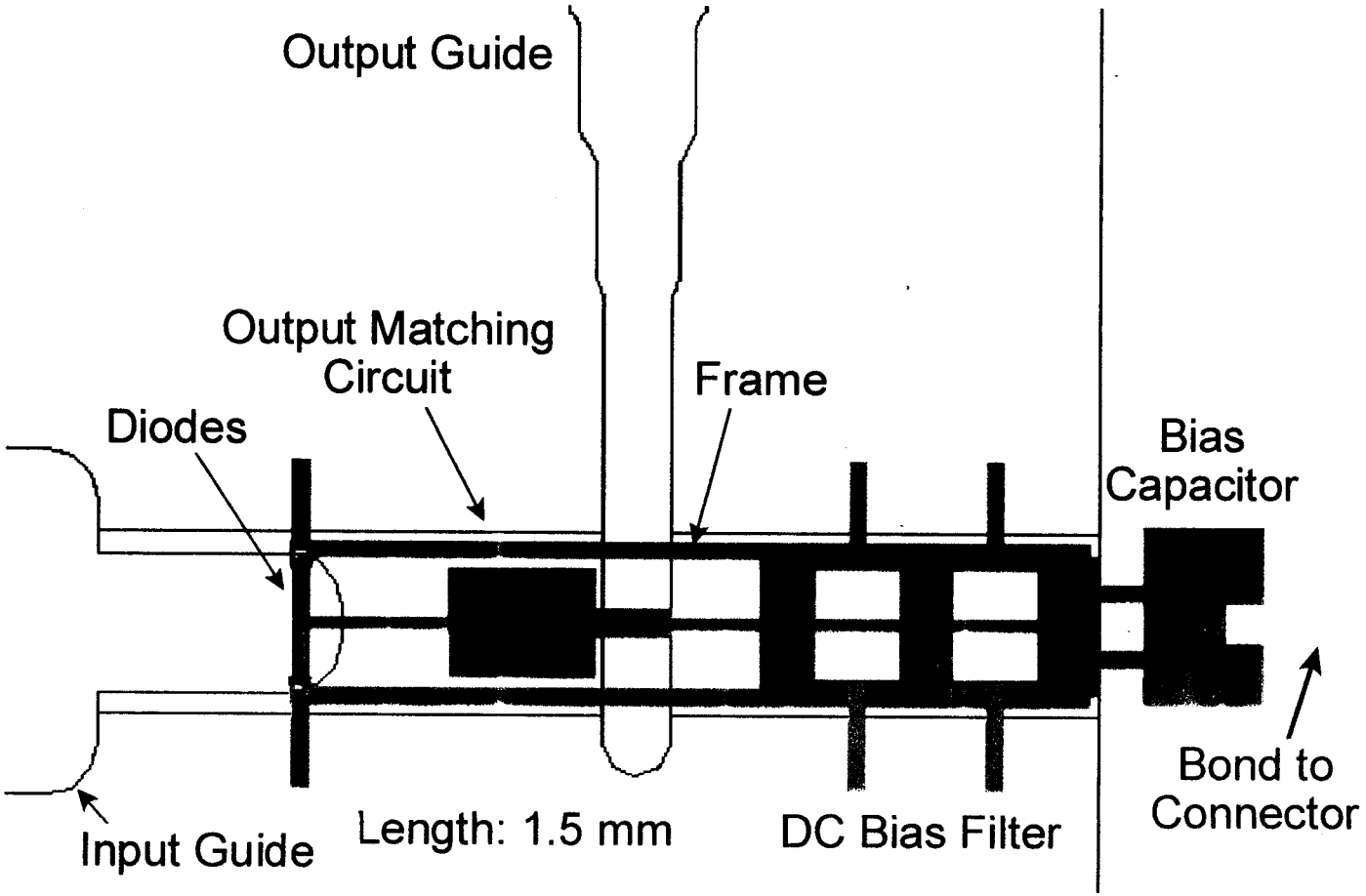


- Chip soldered to block or Quartz
- Bondwires connect quartz to Bias Cap and to block (for chip on quartz version)



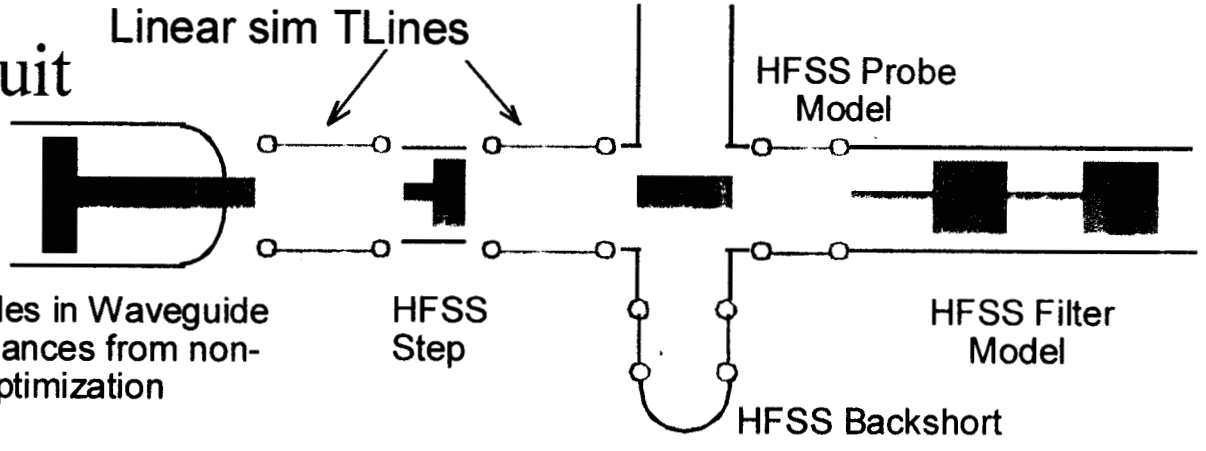
- All chip connections to block made with beam leads
- Diodes integrated into circuit
- GaAs under metal removed for low loss

Substrateless Circuit Mounted in Block

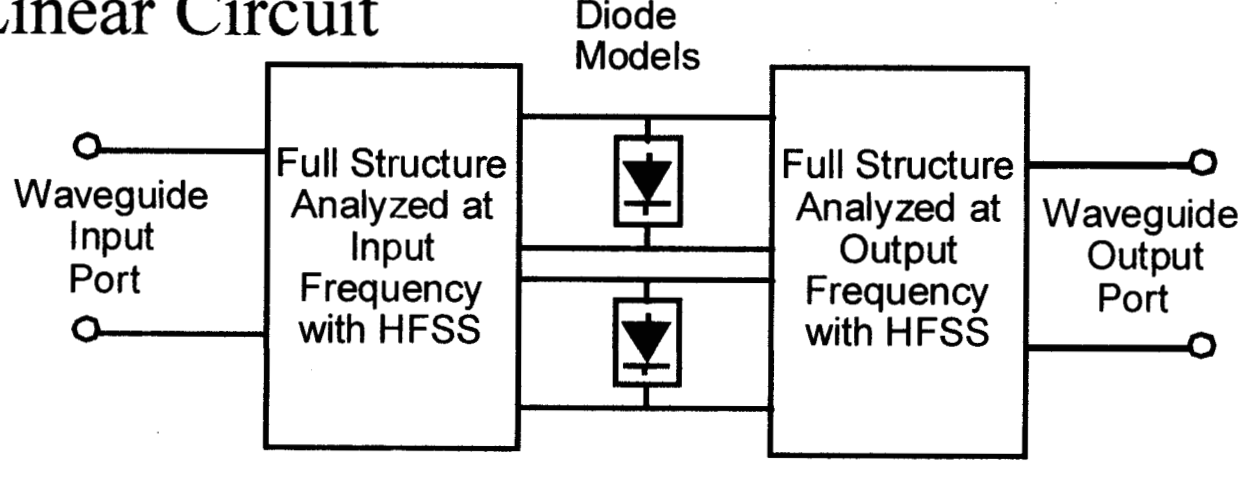


Doubler Design Strategy

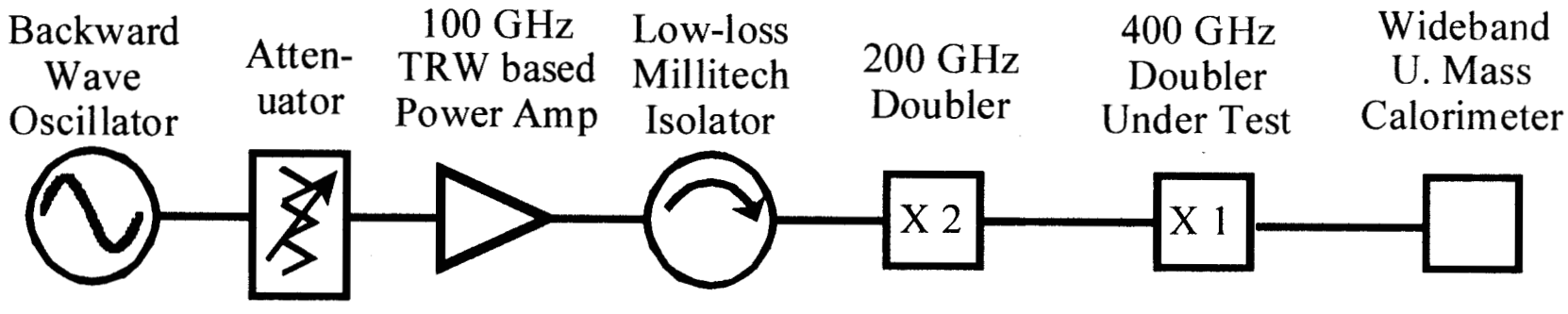
Linear Circuit



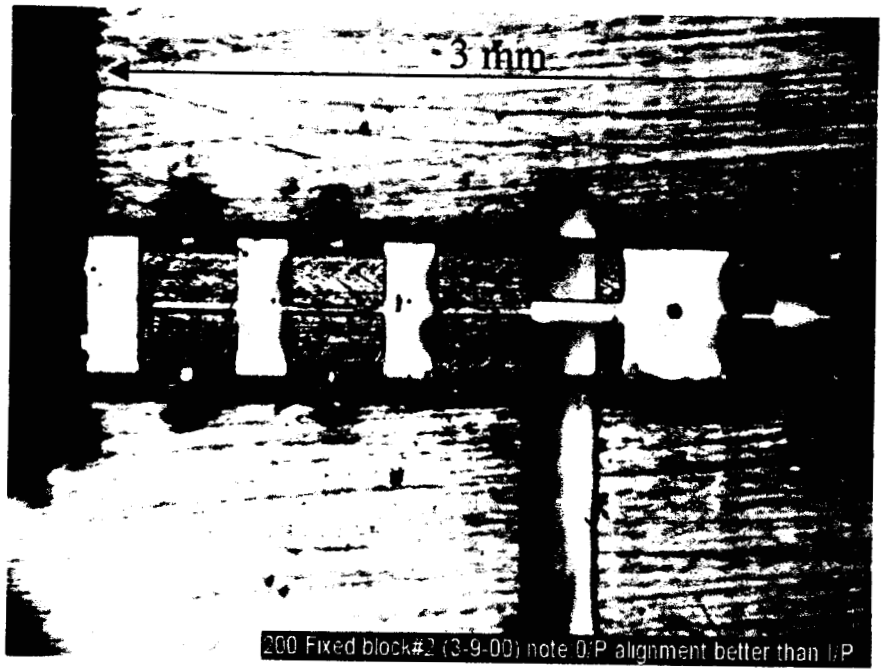
Non-Linear Circuit



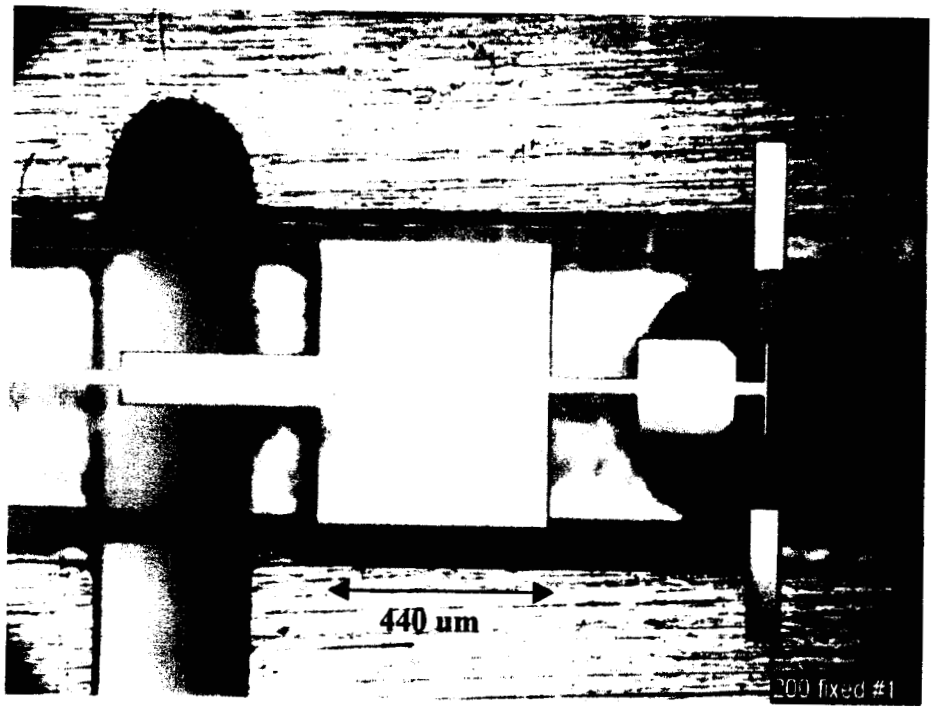
400 GHz Doubler Test Set



Substrateless Technology for 200 GHz MMCs



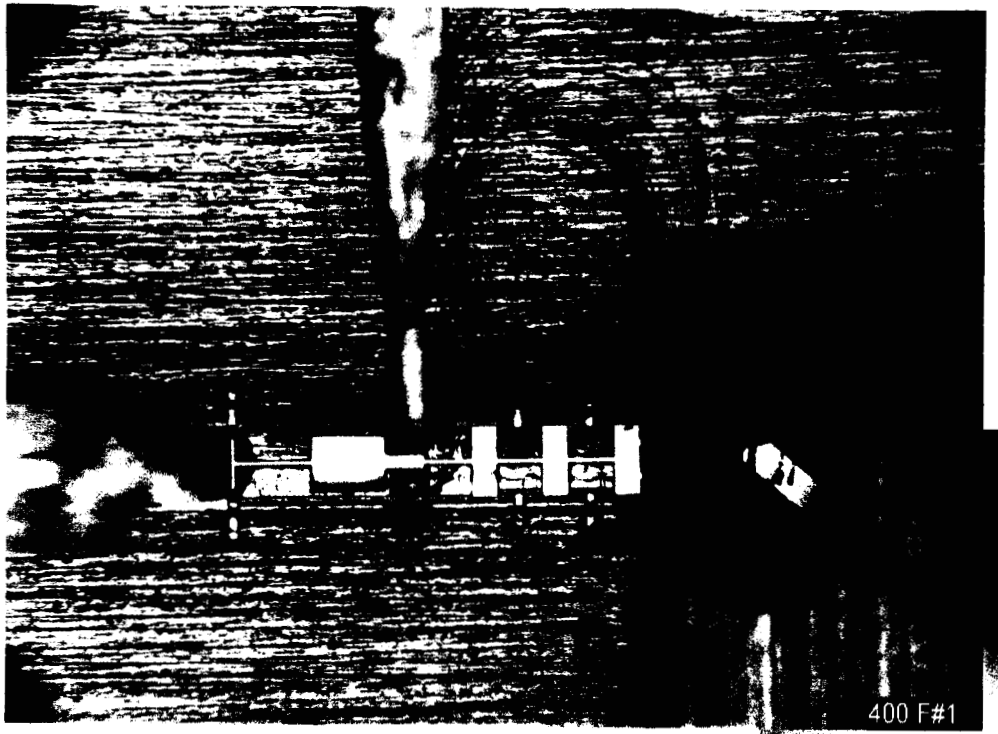
Full view of structure mounted in a waveguide block



Close-up of the anodes

Gives 8% efficiency, despite design flaw

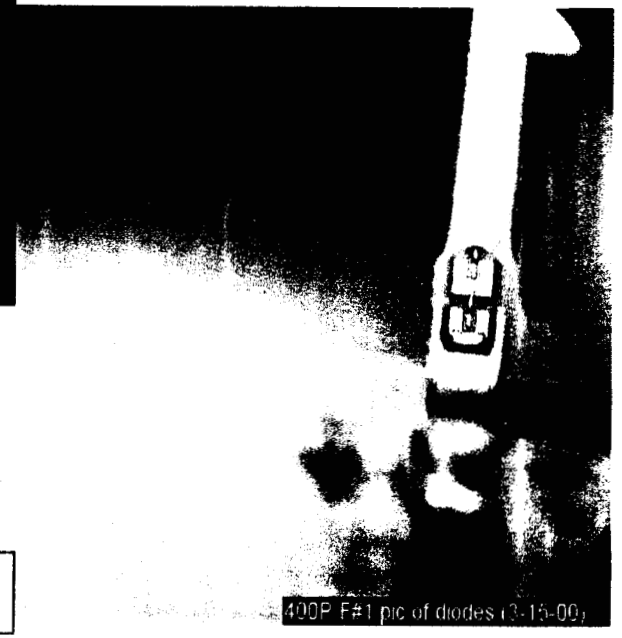
Substrateless Technology for 400 GHz MMCs



Doubler mounted in block

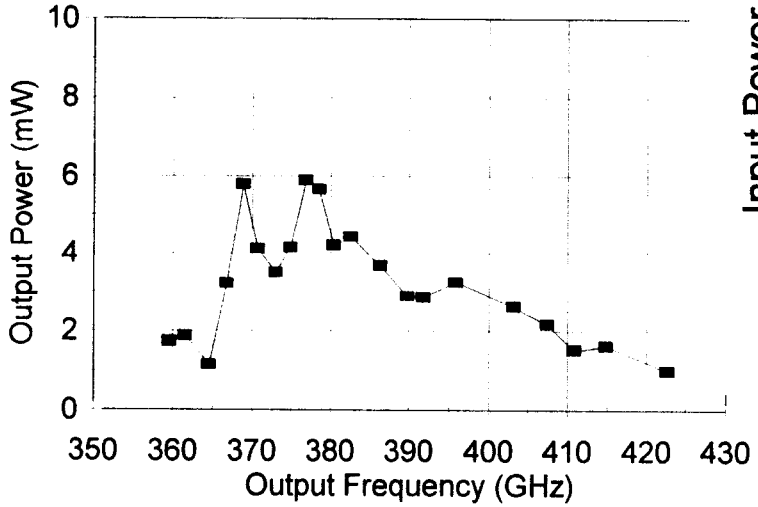
30 um

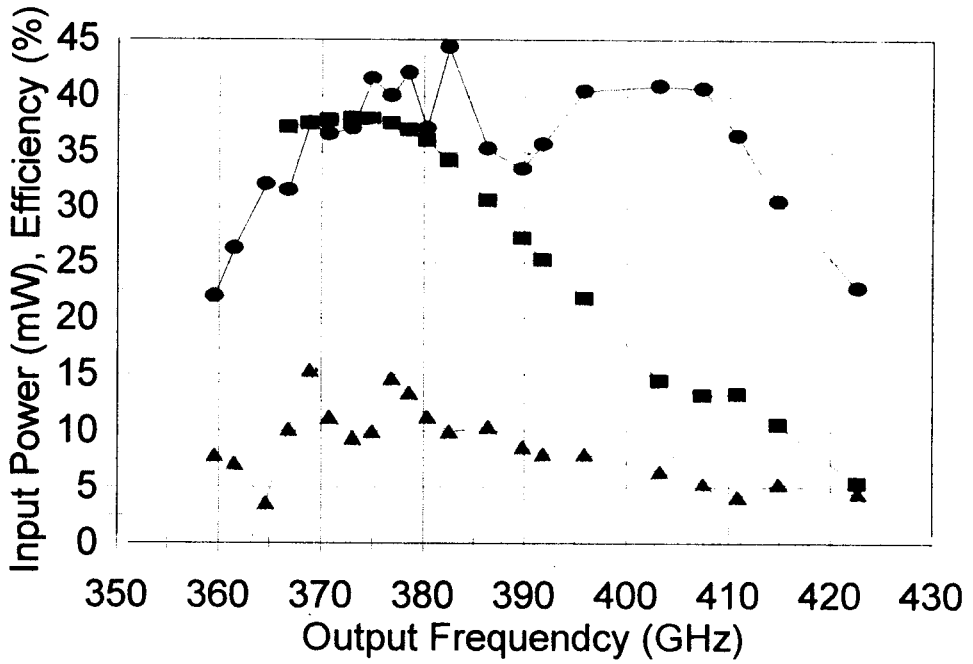
1.5 mm



Closeup of diode on frame

Measured Performance of 400 GHz Doubler

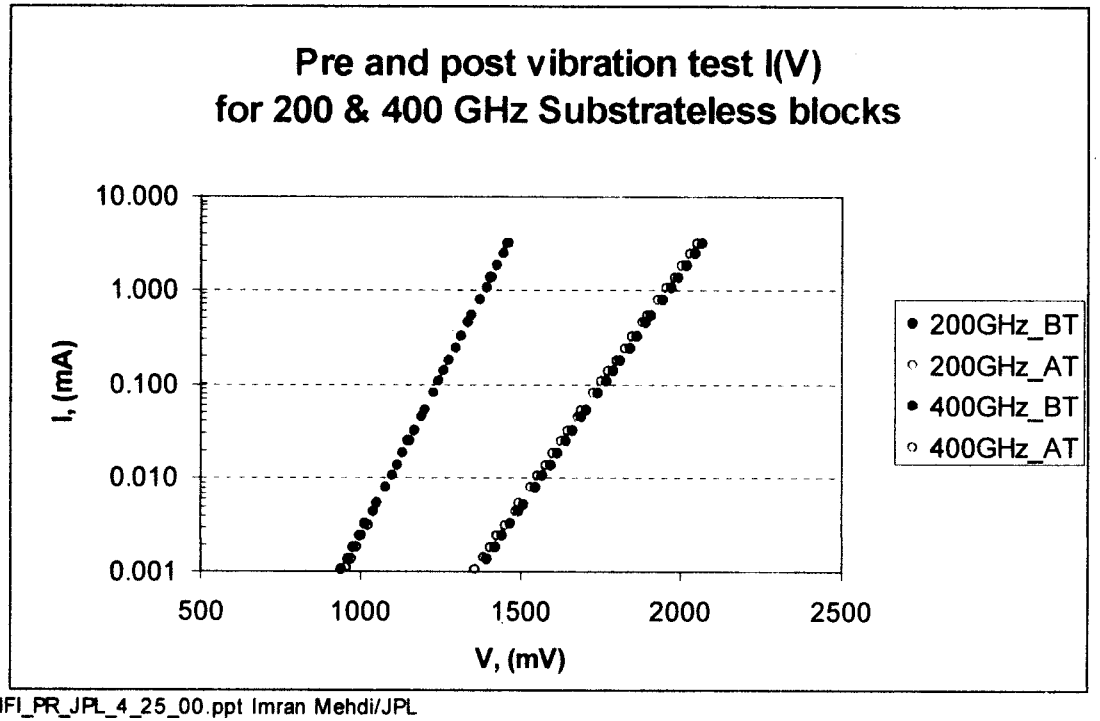




First-order random vibration test on the Substrateless MMCs

- 200 and 400 GHz blocks, length of the block parallel to x-axis

Test I specifications	Test II specifications
20 Hz--0.001 g^2/Hz	20 Hz--0.001 g^2/Hz
20-100 Hz--+6dB/oct	20-100 Hz--+6dB/oct
100-500 Hz--0.1, 0.2,0.4,0.6,0.8,1.0,1.2 g^2/Hz	100-1000 Hz--0.8 g^2/Hz
500-2000 Hz-- -6dB/oct	1000-2000 Hz-- -6dB/oct
Overall: 7.9,10.9,15,18,21,23,28 Grms	Overall: 28.7 Grms
Duration: 60 seconds	Duration: 440 seconds



- **no change in I(V)**
- **no change in RF**

(only 200 GHz measured)

Summary of Problems Being Addressed

- **Blocks had machining errors** — Process corrected, new blocks are much improved and within specifications
- **Input design error on 200 GHz Doubler** — Experience with design procedure improves detection of errors
- **Matching network in channel is sensitive to machining variations, especially low impedance lines** — New design techniques put most matching in waveguide, vastly improving performance and robustness

Conclusions

- Novel substrateless multiplier technology has been developed which fulfills the goals of efficient assembly and high performance
- First substrateless iteration has yielded state-of-the-art power, bandwidth and efficiency at 400 GHz
- 200 GHz doubler being redesigned and fabricated to eliminate errors and improve performance

Lessons Learned from First Iteration

- Assembly takes only **1/2 hour** per block.
- Alignment of circuit with block is very repeatable between blocks.
- Circuits are robust and reliable.
- No soldering or other high temperature assembly procedure needed.
- Thermal questions to be addressed with short beam leads and analysis.